802.1X, EAP and RADIUS

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Security of IT infrastructure (2023/24)

Content

Network access control

802.1X

EAP

RADIUS

Summary

Network access control

- AAA services ~ authentication, authorization, accounting

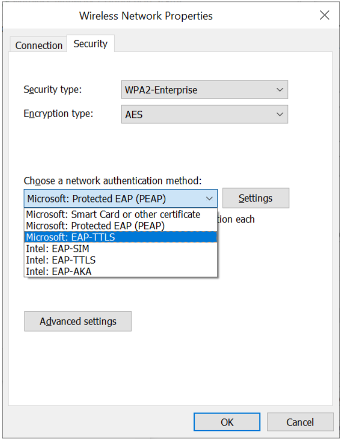
- **authentication**: verification (proving) of subject's identity
- authorization: determining whether the subject can perform given action
- accounting: tracking the use (consumption) of network resources
  - session duration, packets and data transferred, …

IEEE Std 802.1X

- Port-Based Network Access Control
- IEEE standard – latest version: 2020
- the standard:
  - specifies a general method for provision of port-based network access control;
  - specifies protocols that establish secure associations for IEEE Std 802.1AE MAC Security;
    (MAC – Media Access Control, part of a link layer in OSI model),
    encryption and integrity for Layer 2 (default AES-128-GCM)
  - facilitates the use of industry standard authentication and authorization protocols.
- example: WPA2 Enterprise (WPA2-802.1X, Wi-Fi Protected Access II)
  - cf. WPA2 Personal (WPA2-PSK, Pre-shared key)
  - 2018: updated to WPA3 Personal (major update SAE), and WPA3 Enterprise (major update: optional 192-bit mode, prescribed protocols, algorithms, and parameters)

Windows 10

- WiFi; Wired AutoConfig service for 802.1X on wired Ethernet interfaces



Wireless Network Properties

Connection | Security

Security type: WPA2-Enterprise

Encryption type: AES

Choose a network authentication method:

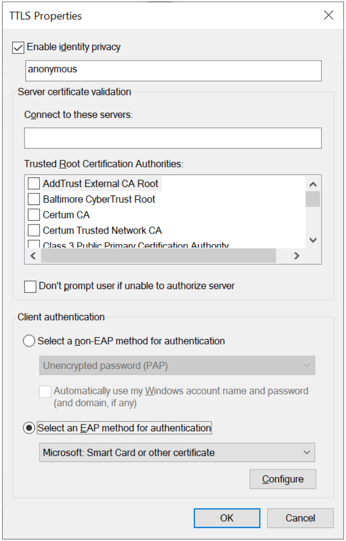
Microsoft: Protected EAP (PEAP) | Settings

Microsoft: Smart Card or other certificate
Microsoft: Protected EAP (PEAP)
Microsoft: EAP-TTLS
Intel: EAP-SIM
Intel: EAP-TTLS
Intel: EAP-AKA

tion each

Advanced settings

OK | Cancel



TTLS Properties

☑ Enable identity privacy

anonymous

Server certificate validation

Connect to these servers:

Trusted Root Certification Authorities:

□ AddTrust External CA Root
□ Baltimore CyberTrust Root
□ Certum CA
□ Certum Trusted Network CA
□ Class 3 Public Primary Certification Authority

□ Don't prompt user if unable to authorize server

Client authentication

○ Select a non-EAP method for authentication

Unencrypted password (PAP)

□ Automatically use my Windows account name and password (and domain, if any)

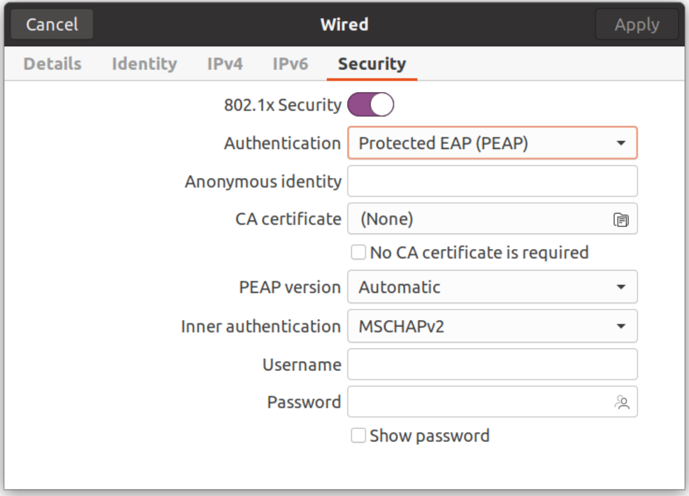
● Select an EAP method for authentication

Microsoft: Smart Card or other certificate

Configure

OK | Cancel

Ubuntu 20.04 (Wired connection)



802.1x Security ●

Authentication: Protected EAP (PEAP)

Anonymous identity:

CA certificate: (None)

□ No CA certificate is required

PEAP version: Automatic

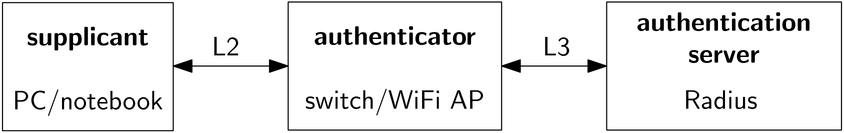
Inner authentication: MSCHAPv2

Username:

Password:

□ Show password

Subjects and roles in 802.1X

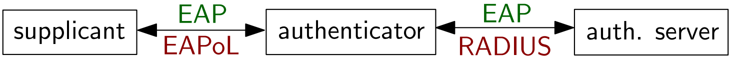


- Supplicant (client)
  - SW, e.g. part of an operating system
  - HW, e.g. Intel AMT (part of Intel vPro platform)
- Authenticator – facilitates authentication of other entities
- Authentication server – provides an authentication service

What’s going on in 802.1X

- initial state: port (access point) is closed for any client’s communication except EAPoL (EAP over LAN)
- client (supplicant) performs authentication against authentication server (EAP, Extensible Authentication Protocol)
    - success: authenticator opens port, assigns VLAN etc.
    - failure: authenticator keeps port closed / opens port and assigns the client to guest VLAN etc.

Protocols in 802.1X



- EAPoL (EAP over LAN)
  - facilitates communication supplicant ↔ authenticator
  - runs over 802.3 (Ethernet), 802.11 (WLAN), …
  - packs EAP messages into L2 communication
- RADIUS …details later
  - communication authenticator ↔ authentication server
  - in this scenario: EAP messages packed into messages of RADIUS protocol

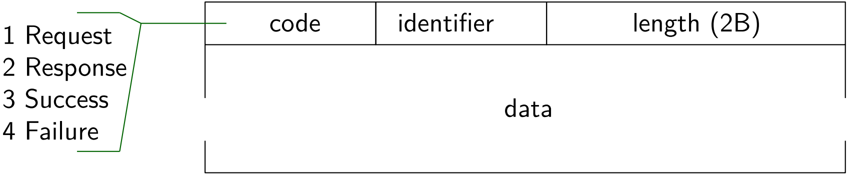
Challenges for deployment

- some EAP methods need certificates – certificate management (provisioning), both server’s and supplicant’s certificates
- network devices without 802.1X support (e.g. printers)
- Wake on LAN
- multiple devices on single network port (IP phones, hub etc.)
- unavailable authentication server

…etc. …

EAP (Extensible Authentication Protocol)

- originally an extension of PPP (Point-to-point protocol), now RFC 3748
- typically over data link layer (e.g. PPP, IEEE 802; i.e. without IP)
- general authentication framework for multiple authentication methods
- packet format:



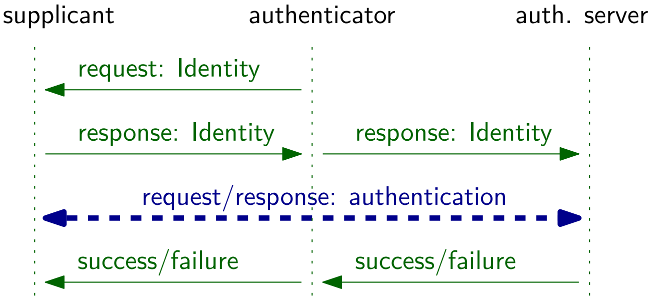
1 Request
2 Response
3 Success
4 Failure

code	identifier	length (2B)
data		

  - identifier aids in matching responses with corresponding requests
  - RFC 5296: additional codes introduced (5 Initiate, 6 Finish)

EAP (2)

- very simple protocol
  - (potentially) large number of request/response messages, usually finished with success/failure
- example:



EAP (3)

- complexity in authentication methods

<table>
<tr><td>1/2</td><td>identifier</td><td>length (2B)</td></tr>
<tr><td>type</td><td colspan="2" rowspan="2">data for particular auth. method</td></tr>
<tr><td></td></tr>
</table>

- examples of authentication methods (more than 40, optional custom extensions):

4	MD5	21	PEAP
13	TLS	43	FAST
21	TTLS	49	IKEv2

EAP-MD5

- defined in the RFC (standard-compliant implementation must support)
  - obsolete, vulnerable, should not used
- implementation CHAP (Challenge Handshake Authentication Protocol):
  - Request: *challenge*
  - Response: MD5(identifier || *shared secret* || *challenge*)
- avoid this method – security problems:
  - only one-sided (client/supplicant) authentication
  - vulnerable to dictionary and brute-force attacks
  - vulnerable to MITM attack …messages in clear-text without any protection of integrity/authenticity
  - identity of client revealed
  - no support for cryptographic key generation – cannot protect further communication
  - …

EAP-TLS, EAP-TTLS and EAP-PEAP

Ideas (outer EAP used mostly for solving packet fragmentation):

- EAP-TLS: using TLS authentication
- EAP-TTLS: client authentication (as AVP) tunneled in TLS
- EAP-PEAP: inner EAP instance tunneled in TLS (example: eduroam)

	EAP-TLS	EAP-TTLS	EAP-PEAP
client certificate	yes	optional	optional
server certificate	yes	yes	yes
mutual authentication	yes	yes	yes
key generation	yes	yes	yes
identity protection of client	no	yes	yes

- using EAP-TLS with TLS 1.3 (RFC 9190)

Some inner authentication methods

- CHAP …with MD5 was discussed before
- MS-CHAPv2 …CHAP variant (defined in RFC 2759)
    - mutual (two-way) authentication
    - free from LAN Manager history
    - generating cryptographic keys
    - frequently used in practice
    - interesting analysis (standalone MS-CHAPv2): *Defeating PPTP VPNs and WPA2 Enterprise with MS-CHAPv2* (DEFCON 20, 2012)

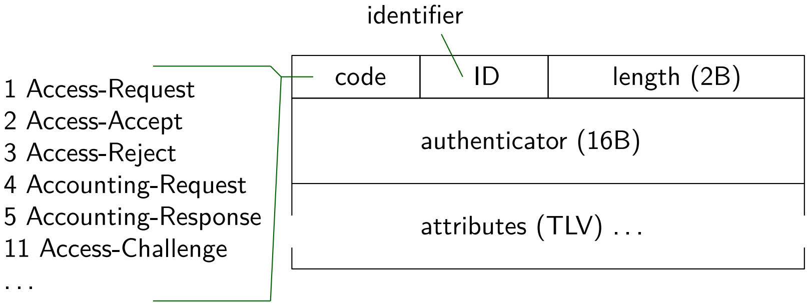
RADIUS

- RADIUS – Remote Authentication Dial In User Service
- RFC 2865, RFC 2866 (Accounting) + other extensions
- centralized authentication of users and systems
- AAA services
- client/server protocol
  - client (NAS – Network Access Server):
    switch, router, access point, VPN server …
  - server (RADIUS server):
    FreeRADIUS, Network Policy Server (Microsoft), Identity Services Engine (Cisco), …

Basic characteristics

- stateless protocol (UDP)
- database of users: SQL database, LDAP, text files, …
- authentication can be verified locally, or by other services (e.g. Active Directory)
- communication client ↔ server (initialized by client)
- proxy RADIUS server (facilitates roaming of users between realms)

Packet



identifier

code | ID | length (2B)

authenticator (16B)

attributes (TLV) . . .

1 Access-Request
2 Access-Accept
3 Access-Reject
4 Accounting-Request
5 Accounting-Response
11 Access-Challenge
. . .

- authenticator:
  - request auth. (in Access-Request packets) – unpredictable and unique over lifetime of a secret
  - response auth. (Access-[Accept, Reject, Challenge] packets) MD5(code || ID || length || request auth. || attributes || secret)
  - secret – password shared by client and server

Security (1)

- user password (P) is transmitted encrypted
  - password padded with 0x00 to multiple of 16 B
  - encryption: $P \oplus \mathrm{MD5}(\mathrm{secret} \,||\, \text{request auth.})$
  - other attributes in clear-text (security?, privacy?)
- value *secret*
  - dictionary attack or brute-force attack (using response auth. or encrypted password)
  - often the same values used in multiple NAS $\Rightarrow$ fake NAS, attacking user passwords

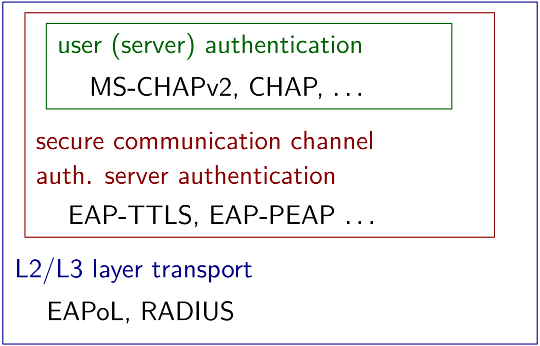
Security (2)

- vulnerable for repeated or predictable value of request authenticator
  - get server's responses in advance and repeat them later (see also Event-Timestamp attribute)
- Access-Request without integrity protection
  - see Message-Authenticator attribute (HMAC-MD5 for entire packet, key is *secret*)
- some risks are mitigated by employing suitable EAP method
- protection of the protocol – providing secure channel
  - IPSec, RadSec – RADIUS over TLS
- RADIUS support for EAP (RFC 3579)

Alternatives and improvements

- TACACS+ (Terminal Access Controller Access-Control System)
  - proprietary Cisco protocol, primary for access to network components
  - over TCP, separation of authentication and authorization
  - (optional) encrypted body of the packet (without header)
- DIAMETER
  - intended replacement for RADIUS (slow adoption)
  - basics defined in RFC 6733
  - uses reliable transport layer (TCP, SCTP)
  - secure communication channel – recommended TLS/TCP and DTLS/SCTP
  - both stateful and stateless models
  - easy to extend, …
  - example usage: LTE (Long-Term Evolution) networks

Summary – architecture (802.1X example)



user (server) authentication

MS-CHAPv2, CHAP, . . .

secure communication channel

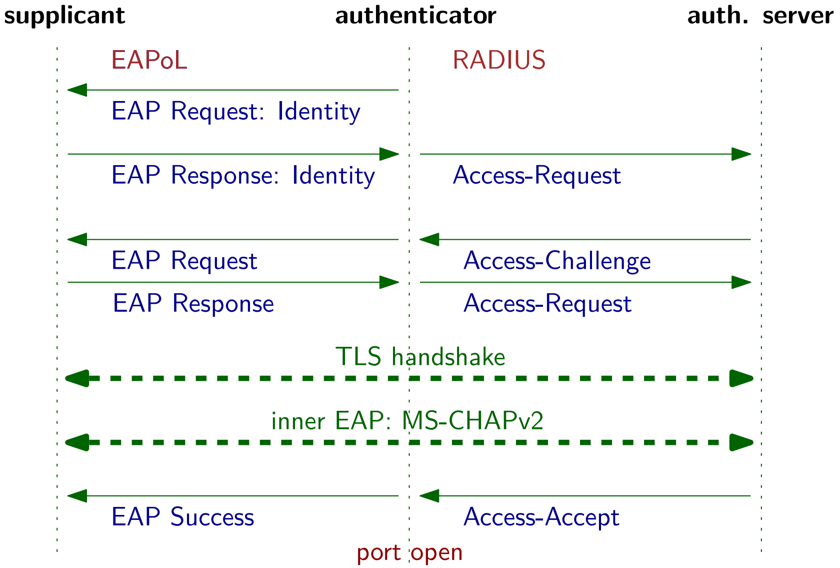
auth. server authentication

EAP-TTLS, EAP-PEAP . . .

L2/L3 layer transport

EAPoL, RADIUS

Summary – messages (802.1X example)


supplicant
authenticator
auth. server
EAPoL
RADIUS
EAP Request: Identity
EAP Response: Identity
Access-Request
EAP Request
Access-Challenge
EAP Response
Access-Request
TLS handshake
inner EAP: MS-CHAPv2
EAP Success
Access-Accept
port open